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FINAL REPORT ON ELECTRONICS RESEARCH AT THE UNIVERSITY OF TEXAS AT AUSTIN

NO. 39

For the period April 1, 1986 through March 31, 1989

JOINT SERVICES ELECTRONICS PROGRAM

Research Contract AFOSR F49620-86-C-0045

May 31, 1989

ELECTRONICS RESEARCH CENTER

Bureau of Engineering Research
The University of Texas at Austin
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Submitted by Edward J. Powers

on behalf of the Faculty and Staff

of the Electronics Research Center

May 31, 1989

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This final report covers the period from April 1, 1986 through March 31, 1989. The progress reported concerns research conducted by ten faculty members and approximately thirty graduate students from the Department of Electrical and Computer Engineering and the Department of Physics. The University of Texas DoD JSEP program is a broad-based program with four research units in Solid State Electronics, two in Electromagnetics, two in Quantum Electronics, and two in Information Electronics.

Solid State Electronics includes work on implantation and annealing of InP and related compounds; molecular beam epitaxy with high-speed device applications; epitaxial growth, structure and electronic properties of silicides on silicon surfaces; and femtosecond processes in condensed matter. In Quantum Electronics, nonlinear optical interactions and nonlinear Raman scattering from molecular ions have been investigated. Work in Electromagnetics includes millimeter-wave monolithic array components and nonlinear wave phenomena, while electronic signal processing and nonlinear estimation and detection have been studied in Information Electronics.

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OVERVIEW

I. OVERVIEW

This Final Report covers the thirty-six month period ranging from April 1, 1986 through March 31, 1989. Ten faculty members and approximately twenty graduate students from the Department of Electrical and Computer Engineering and the Department of Physics conducted the research described in this report. The University of Texas DoD JSEP program is a broad-based program with four research units in Solid State Electronics, two in Electromagnetics, two in Quantum Electronics, and two in Information Electronics.

CURRENT STATUS

Solid State Electronics: We have developed extensive laboratory facilities for MBE growth and analysis of semiconductor materials, along with appropriate device fabrication capabilities. Using an extremely versatile computer-enhanced image processing system for reflection high energy electron diffraction (RHEED) on our Varian Gen II MBE machine, we are able to study the details of MBE growth at the submonolayer scale. We have also developed extensive analytical capabilities including temperature dependent Hall effect, low temperature photoluminescence, photoluminescence excitation spectroscopy, deep level transient spectroscopy, and other techniques for examination of MBE grown layers and structures. These capabilities allow us to not only examine details of MBE growth at the monolayer and submonolayer scale, but also to use the resulting controlled growth for device development and studies of transport properties in semiconductor multilayers.

We have applied the imaging RHEED system described above to study the effect of growth interruptions on interface quality, and also to accurately control the dimensions of resonant tunneling structures. This system is also used routinely as an in-situ measure of alloy composition. We have shown that significant changes in the principal RHEED streak intensity and shape are produced by very small changes in adatom coverage and that the profile is noticeably different for Ga and As stabilized surfaces.

In pursuing this work we have also studied MBE growth techniques and have made improvements in the system. We have shown that carbon compounds are produced by the substrate rotation mechanism, and the rate of evolution is proportional to the rotation speed. We have developed and installed a refractory, two-zone, large capacity arsenic cracking source for providing As_2 for MBE growth. This system provides As_2/As_4 flux ratios of 6-8 over a wide range of cracking furnace temperature.

In device development, we have grown high quality normal and inverted AlGaAs/InGaAs High Electron Mobility Transistor (HEMT) structures on GaAs substrates by MBE, and studied the influence of rapid thermal annealing (RTA) on electrical conduction in the two-dimensional electron gas (2-DEG).

We have invented a new transit-time device in which electrons are injected into the drift region through a resonant tunneling structure rather than by avalanche injection as in a conventional IMPATT. This device, called the Quantum Well Injection Transit-Time (QWITT) diode, is an extremely promising extension of resonant tunneling structures for high-speed device applications. Simulations clearly indicate that significant improvements in output power over conventional quantum well oscilators will be achieved. We have grown high quality quantum well devices of this type by MBE, and are at present performing dc testing on prototype devices. In addition, pseudomorphic growth such as that described above should allow us to fabricate new types of quantum well structures, providing improvements in QWITT diode performance.

In addition, femtosecond optical techniques have been developed and it is anticipated that this capability will be exploited to measure and understand the basic electron scattering and transport phenomena which underlie the electronic characteristics of III-V materials and devices.

Information Electronics: Our information electronics program rests upon recent progress in extracting information from signals that would otherwise not be obtainable if conventional algorithms were employed. We have made important contributions in the development of novel methods of information extraction and processing. Our recent research in the analysis and processing of signals from different sensors has demonstrated that multisensor fusion is a powerful approach for signal processing and interpretation. We have recently developed a system for hierarchical integration of information extracted from thermal and visual sensors, which provides new information not available by processing either kind of image alone.

We have also developed and analyzed new adaptive nonlinear estimation algorithms for the extraction of information concerning the state of a nonlinear stochastic system with unknown parameters in the system model. The convergence and optimality of the algorithms has been analyzed completely; this is the first such analysis of an adaptive nonlinear estimation algorithm. As a first step toward the analysis and control of "hybrid" dynamical systems containing both discrete and continuous variables, we have made important contributions in the modeling and control of discrete event dynamical systems. These and our other efforts have considerably advanced the state-of-the-art in the development of innovative techniques for information extraction and have enabled us to develop the expertise to make significant contributions in the future.

Electromagnetics: The current work in electromagnetics involves, in a general sense, wave interactions. For example, we note that most of the circuit configurations presently used in monolithic and millimeter-wave integrated circuits are not designed with the interaction of the electromagnetic wave and the devices (both active and passive) in mind. A number of new integrated circuit configurations for mixers and receivers for quasi-optical applications have been conceived, designed, and tested.

Three different quasi-optical planar circuits have been successfully developed for millimeter-wave receiver applications. They are: a balanced mixer with an integrated Gunn local oscillator, a balanced mixer with an integrated MESFET local oscillator and a self-oscillating HEMT receiver front end. All of them make use of the inherent electromagnetic isolation of the even and odd modes of a coupled slot antenna which is simultaneously used as a portion of the local oscillator circuits. They were designed based on the careful electromagnetic analysis and the solid state device characterizations of the constituent elements. This is the first time that all essential elements of millimeter-wave receiver front end are integrated coherently in a quasi-optical manner.

With regard to the nonlinear wave research, we have succeeded, during the current triennium, in demonstrating an approach to measure complex three-wave coupling coefficients, and to the best of our knowledge, this is the first time that such measurements have been made for turbulent-like "incoherent" fluctuation data. Our approach to estimating the complex three-wave coupling coefficients is based upon measurement of a quadratic transfer function, given two channels of raw time series data representing the fluctuation field observed at two spatial points. Most work in nonlinear systems modeling assumes the "input" is Gaussian, an assumption that is clearly unacceptable here, since the fluctuation waveform is nonGaussian due to its past nonlinear history. Thus an important part of the current research program is to develop an approach valid for nonGaussian "inputs". The success of this later objective not only made it possible to make the first measurements of three-wave coupling coefficients and associated energy cascading but appears to have great "technology transfer" potential to other areas of science and engineering.

Quantum Electronics: In our research dealing with dynamical instabilities in optical systems extensive quantitative characterizations of time-dependent steady states have been made for a passive bistable system composed of fundamental elements (two-level atoms in an optical cavity). Our investigations have demonstrated the complete inadequacy of theoretical analysis based upon models that neglect the transverse structure of the electromagnetic field in the cavity. The findings are significant in that broad regions of stable operation are demonstrated in domains that were previously thought to lead exclusively to dynamic instability. Further, these measurements in optical bistability represent one of only a few examples in optical physics for which absolute comparisons with theory for dynamical instabilities have been made. We have also made and reported on significant progress on innovative nonlinear Raman scattering techniques which offer improved capabilities to study the formation and dynamics of molecular ions in discharges.

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D. P. Neikirk, Associate Professor of Electrical and Computer Engineering

B. S. Streetman, Professor of Electrical and Computer Engineering

DEGREES AWARDED

DEGREES AWARDED

Ph.D.

Yuan-Fang Wang, May 1987, "Integration of Active and Passive Sensing Techniques for Representing Three-Dimensional Objects."

Nagaraj Nandhakumar, August 1987, "Multisensor Fusion for Scene Perception - Integrating Thermal and Visual Imagery."

Jose Araya-Pochet, December 1988, "Magneto-optical Studies of Fe, Ni, and V Epitaxial Ultra Thin Films on Ag(100) and Ag(111) Substrates."

Nag Un Song, May 1986, "A Study of GaAs MESFET Modeling by Numerical Simulation."

Samir M. El-Ghazaly, May 1988, "Analysis and Improvement of MM-Wave GaAs MESFET."

Vincent Hwang, May 1988, "Planar Integrated Quasi-Optical Receivers."

Roger H. Taylor, December 1988, "The Development of the Raman-Induced Kerr Effect as a Sensitive Spectroscopic Probe."

Jacek Borysow, June 1986, "Coherent Raman Spectroscopy."

Min Xiao, May 1988, "Quantum Fluctuations in Nonlinear Optics."

Hong-Gi Lee, August 1986, "Linearization of Nonlinear Discrete Time Control Systems."

Hangju Cho, August 1988, "Supremal and Maximal Sublanguages Arising in Supervisor Synthesis Problems with Partial Observations."

K. I. Kim, May 1986, "Frequency Domain Modeling of Quadratic Systems with Random Inputs."

C.W. Farley, December 1986, "The Influence of Stoichiometric Variations on the Site Selection and Electrical Activity of Amphoteric Dopants in Gassium Arsenide and Indium Phosphide."

T.S. Kim, December 1987, "Photoluminescence Studies of Processing-Induced Defects in InP and GaAs."

S.D. Lester, December 1987, "Photoluminescence Studies of Indium Phosphide."

DEGREES AWARDED

M.S.

Harish Asar, December 1988, "Pyramid Based Image Segmentation Using Multisensory Data."

Cameron McCaa, December 1986, "Cryomicroscopic Determination of the Transient Permeability Parameters of Monocyte Cells at Sub-zero Temperatures."

Yu-De Lin, May 1987, "Metal-Insulator-Semiconductor and Optically-Controlled Slow-Wave Structures."

Amir S. Mortazawi, December 1988, "Nonlinear analysis of monolithic QWITT Oscillator."

Vijay Kesan, December 1986, "Quantum Well Devices "

T.R. Block, May 1986, "Rapid Thermal Annealing System for the Processing of III-V Compound Semiconductors."

S.A. Chalmers, May 1986, "An In-Depth Analysis of the Kelvin Resistor Structure."

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K. Sadra, December 1988, "Monte-Carlo Studies of Electron-Hole Scattering and Minority-Electron Transport in Gallium Arsenide."

S. W. Nam, May 1987, "Estimation of the Transfer Functions of a Quadratic Nonlinear System."

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